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delayRatio: A GW Event Physical Likelihood Estimator Based on Detection Delays and SNR Ratios

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Introduction

- This work is part of the GW event follow-up pipeline to evaluate the 'sanity' of the candidate.
  - The pipeline does not produce a yes/no conclusion, more like no/maybe.
- Given a detection delay between detectors and the strength of the event in each, what is the likelihood that the event falls within physical bounds?
  - Assume:
    - ***well defined detection delay***
    - ***identical detectors***
    - ***unpolarized gravitational waves***

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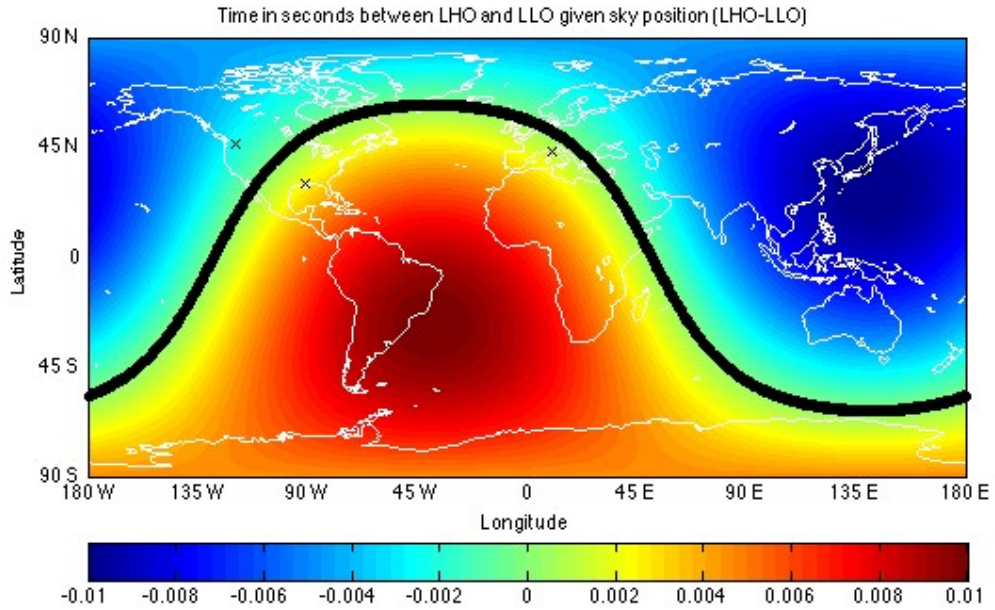
Detection delays



A ring of sky locations is constrained using the detection delay between the 2 LIGO detectors.

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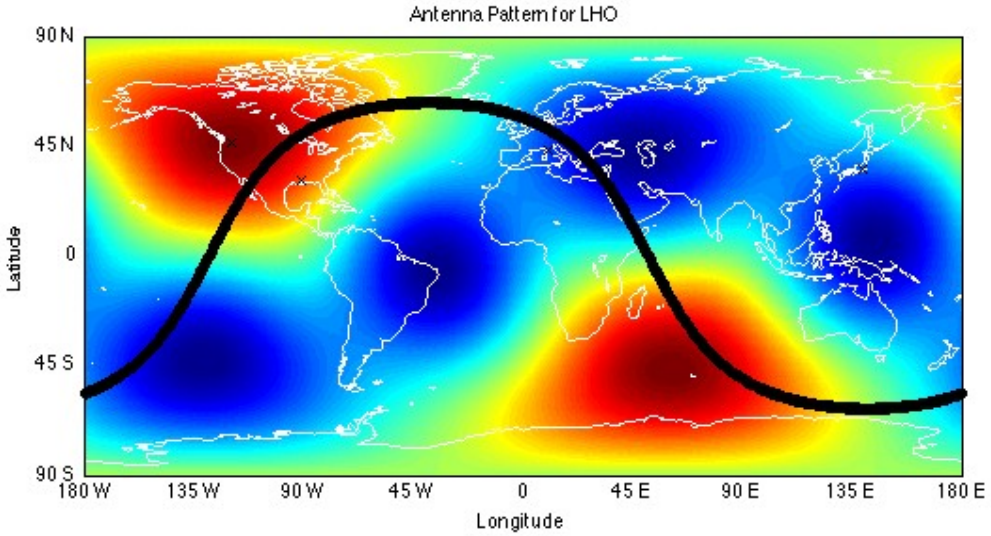
Event Strengths in Detectors

- The possible sky location circle is then projected onto the antenna pattern for each detector.
- The strength of the event (SNR) is the polarization averaged combination of the coefficients:

$$\rho = F_+^2 + F_\times^2$$

- The maximum and minimum ρ are set as the maximum and minimum bounds for that time delay.



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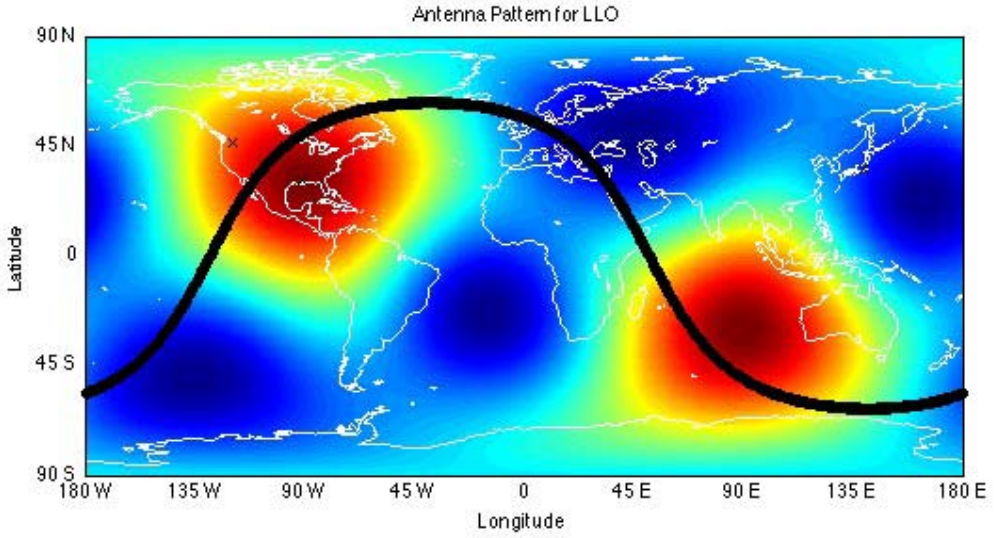
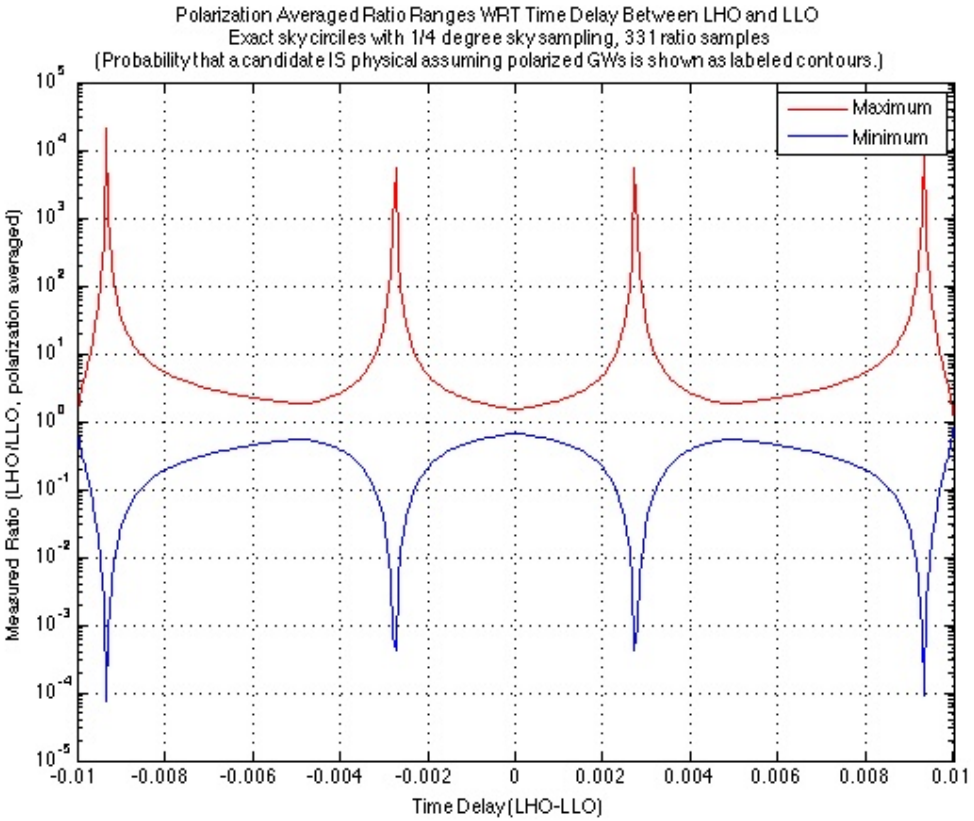


Event Strength Bounds WRT Detection Delay

The following is the maximum and minimum bounds on the signal strength ratios between detector WRT detection delay.

- Poles and zeros correspond to the sky circle passing over antenna pattern zeros



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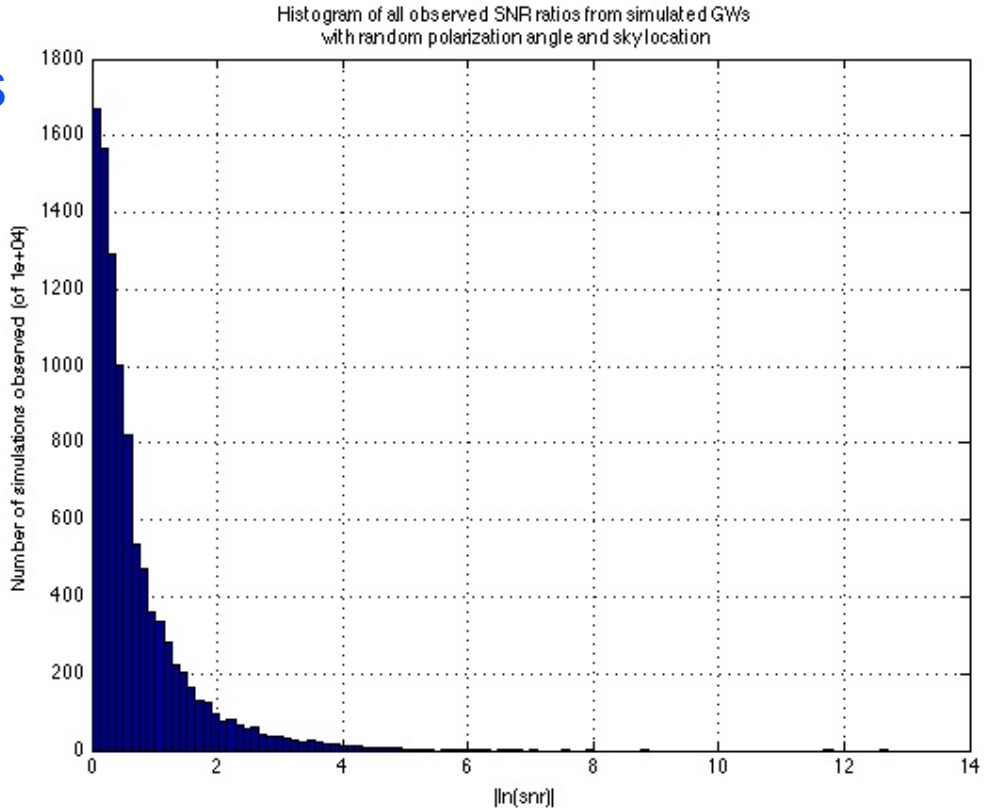
The Effects of Polarization

- Everything thus far has only considered unpolarized gravitational waves.
- The effects of polarization can pull physically possible gravitational waves outside of the unpolarized bounds.
- This effect was observed using 10^4 simulations of randomly distributed source locations with random polarization angles.
- The distribution of ratios around unity is independent of detection delay.

Polarization Ratio Distribution

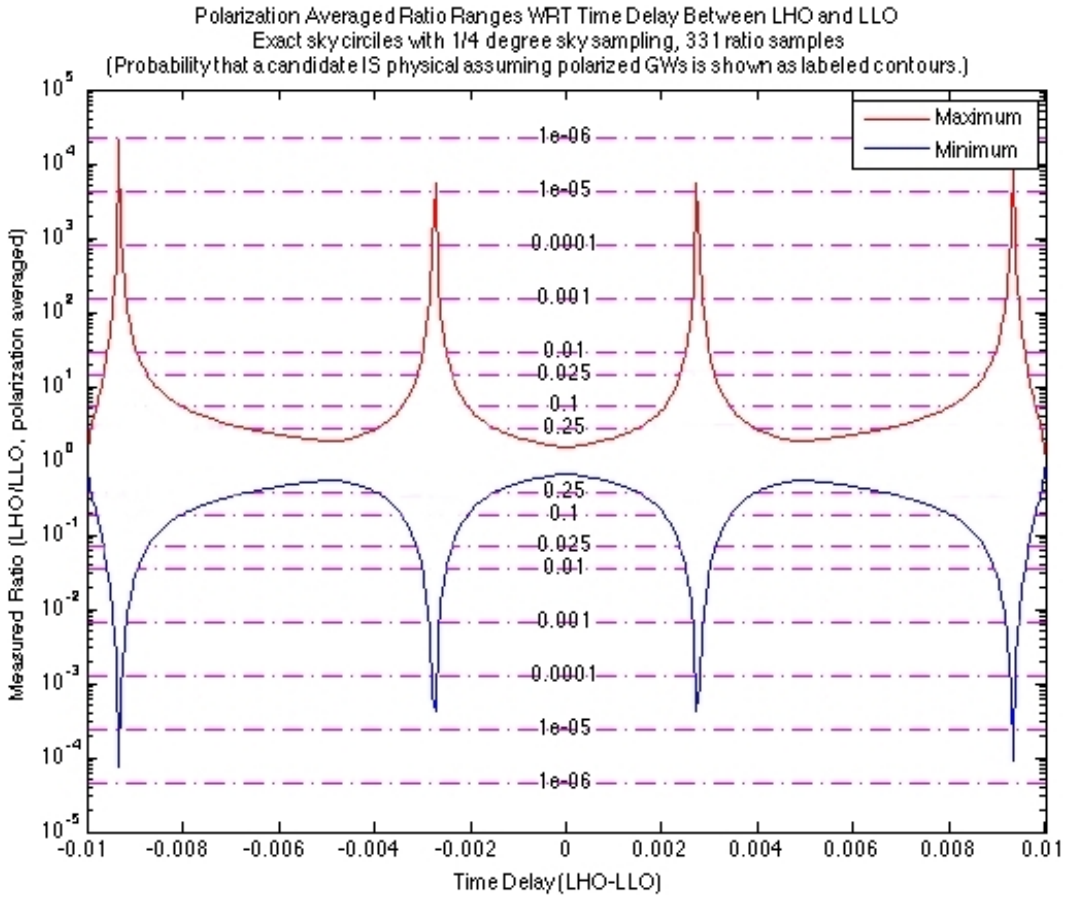
- Taking |ln(SNR)| yields an exponential distribution in ratios around unity.



- The CPD for LHO and LLO is:

$$P(|\ln(SNR)|) = 1 - \exp(-0.726479\,|\ln(SNR)|)$$

Combined Figure of Merit



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Practical Application

- Real detection delays with uncertainty
  - If a part of the range of timing uncertainty (given a SNR) is inside bounds, identify the event within the bounds. Measurement probabilities including polarized waves are unaffected by timing errors.
- Signal strength uncertainties need to be estimated
  - If a part of the range of signal strength (within error bars) is inside bounds, identify the event within the bounds; return probability ranges for polarized waves.
- Using non-identical detectors
  - This investigation assumes that the measured event strengths are comparable between detectors. Manipulations of parameters (applying noise profiles, etc.) must be done prior to (outside of) this likelihood estimation.

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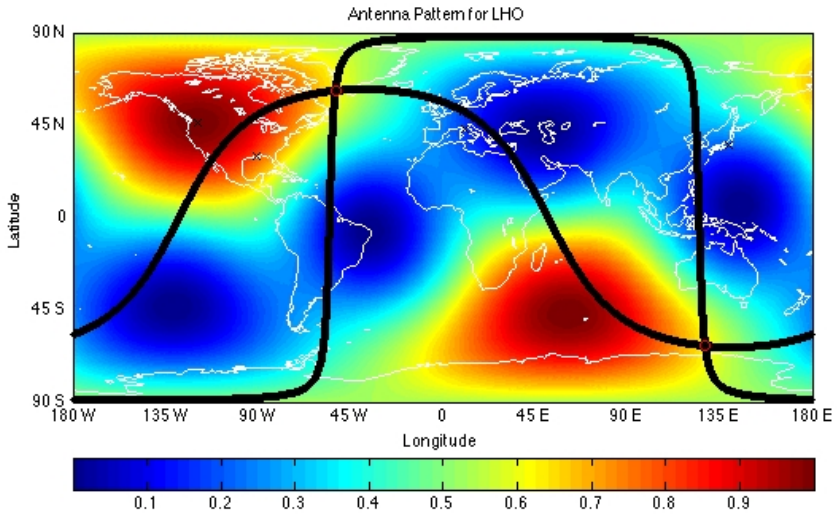
Generalization to 3+ Detectors

- Using 3+ detectors diminishes the importance of event strength consideration.
  - » Timings isolate two sky locations well; event strength suggests a single location
- This work is easily modified to determine source location(s):



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Summary

- The figure of merit has been determined for all combinations of LIGO and VIRGO/GEO/TAMA.
- The results of this analysis produces a yes/maybe answer regarding the physicality of the event.
  - If the answer is maybe, the probability measure indicates “how maybe” (the higher the probability, the more likely the event is physical).
- Generalization to 3+ detectors is dominated by the physicality of the detection delays.
- This analysis can also be applied for source localization based on detection delays only.